CRISM

Introduction to CRISM

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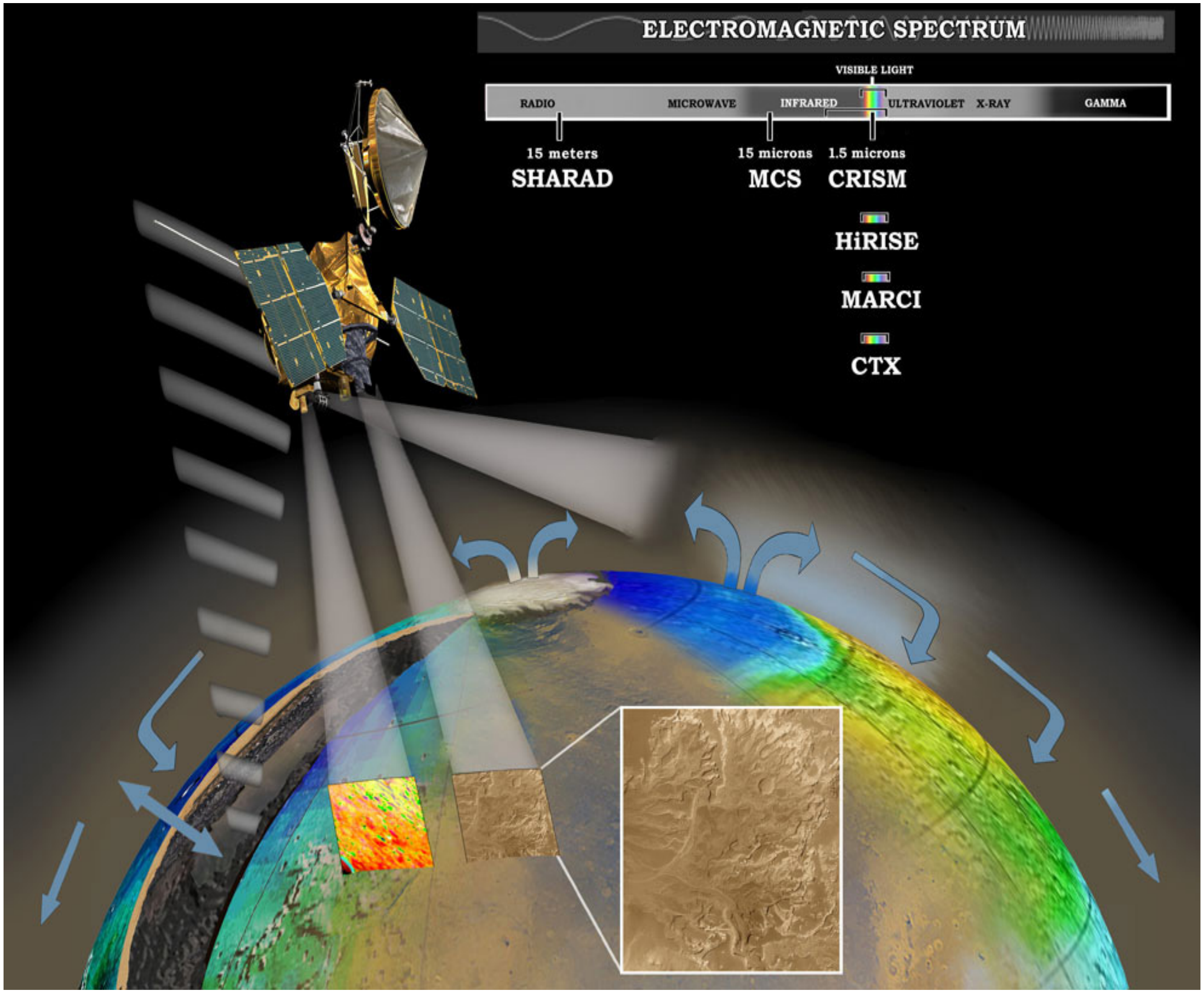
CRISM is 1 of 6 MRO Instruments to Map Mars' Surface and Atmosphere



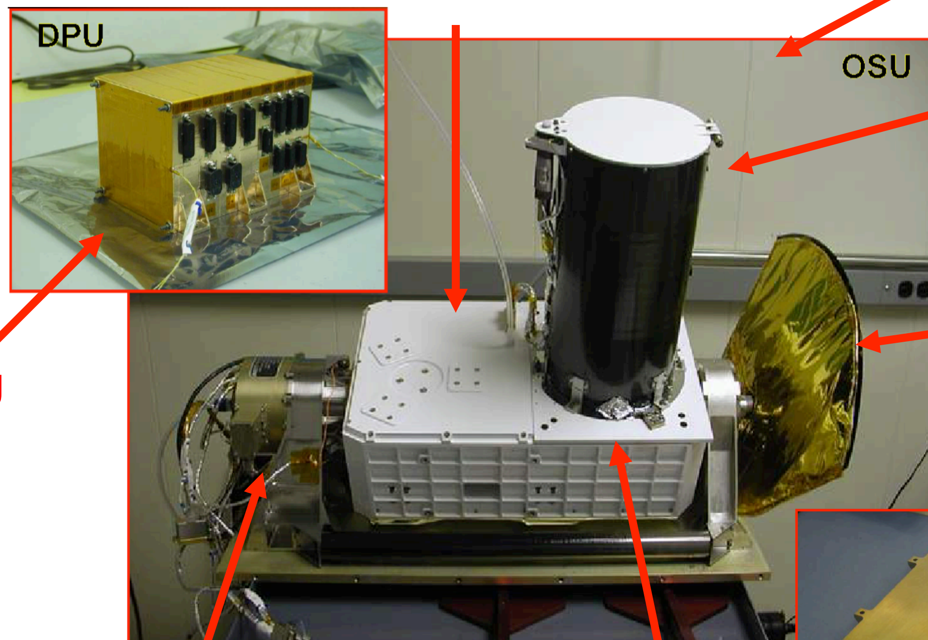
CRISM, HiRISE, CTX, and SHARAD characterize surface geologic features

MARCI, MCS, and CRISM track spatial and seasonal variations in the atmosphere

CRISM Hardware Overview

3 cryocoolers keep IR detector at 110-125K to control noise

Optical Sensor Unit



Baffle with 1-time deployed cover cuts out of field stray light

Radiator pointing toward evening terminator cools spectrometer optics to -70C to -80C

Data Processing Unit controls data acquisition, pixel binning, data editing

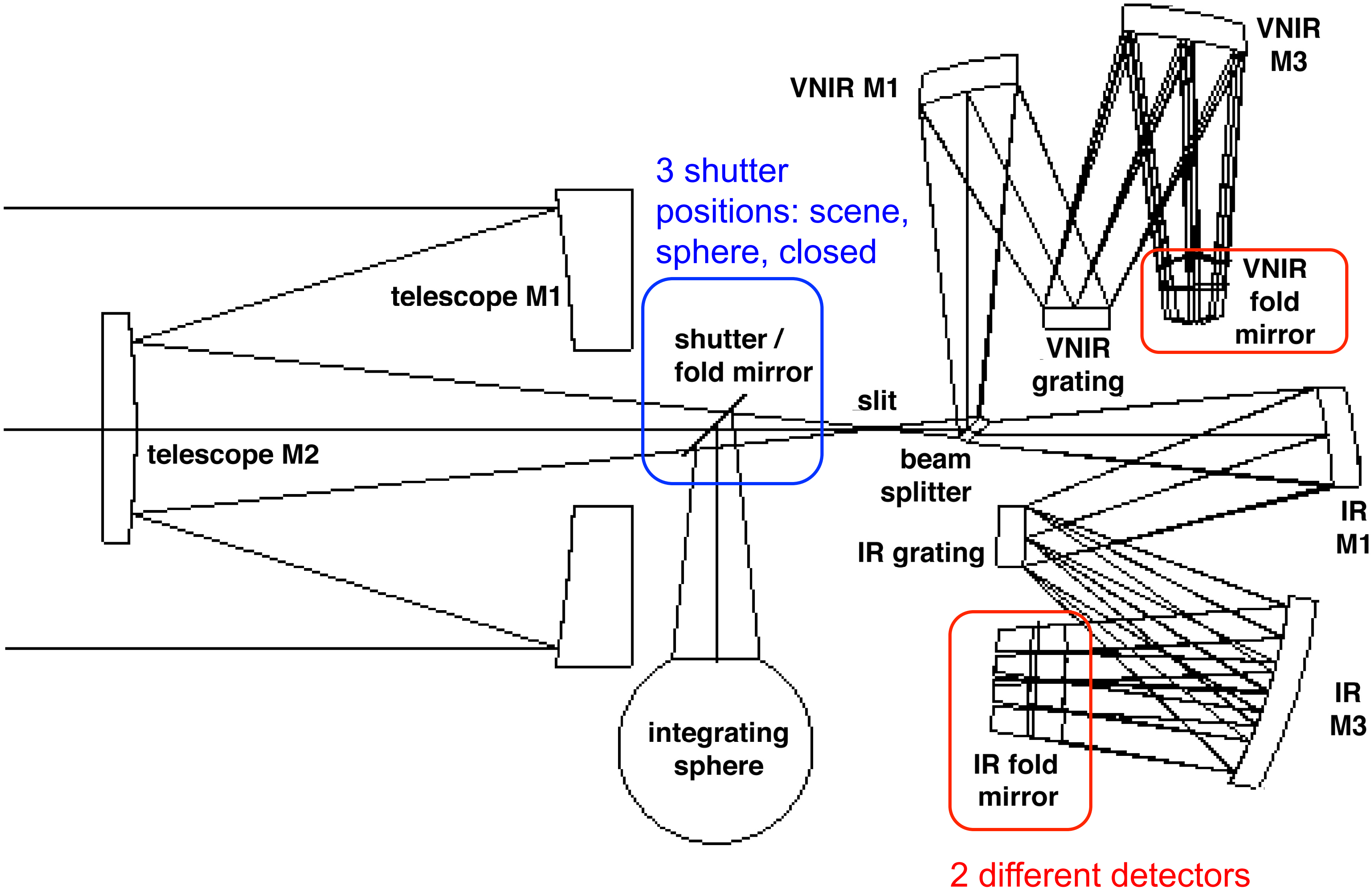
Gimbal Motor Electronics controls gimbal

Gimbal allows observations at multiple geometries to separate surface and atmosphere (±60° along-track)

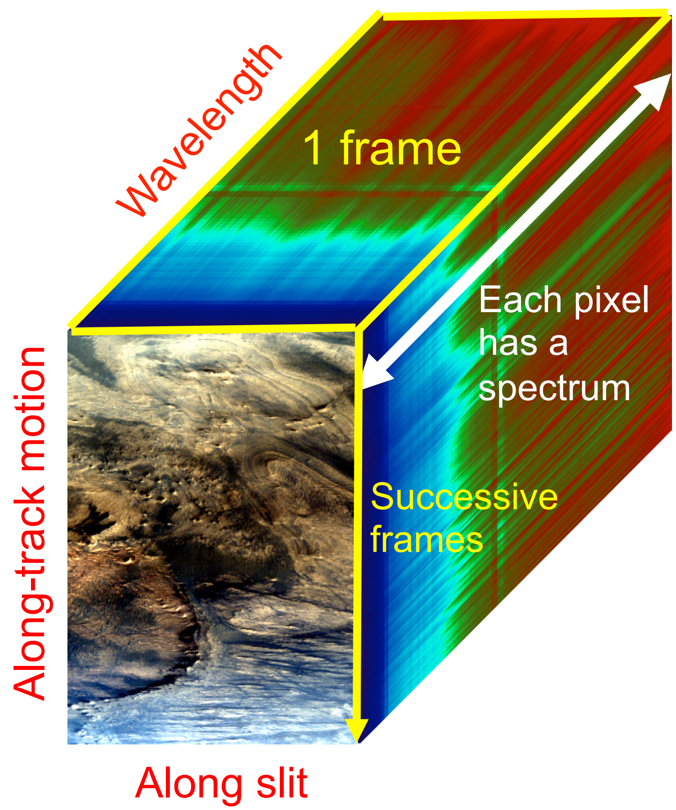
Internal calibration: shutter for dark measurements, integrating sphere for radiometric calibration

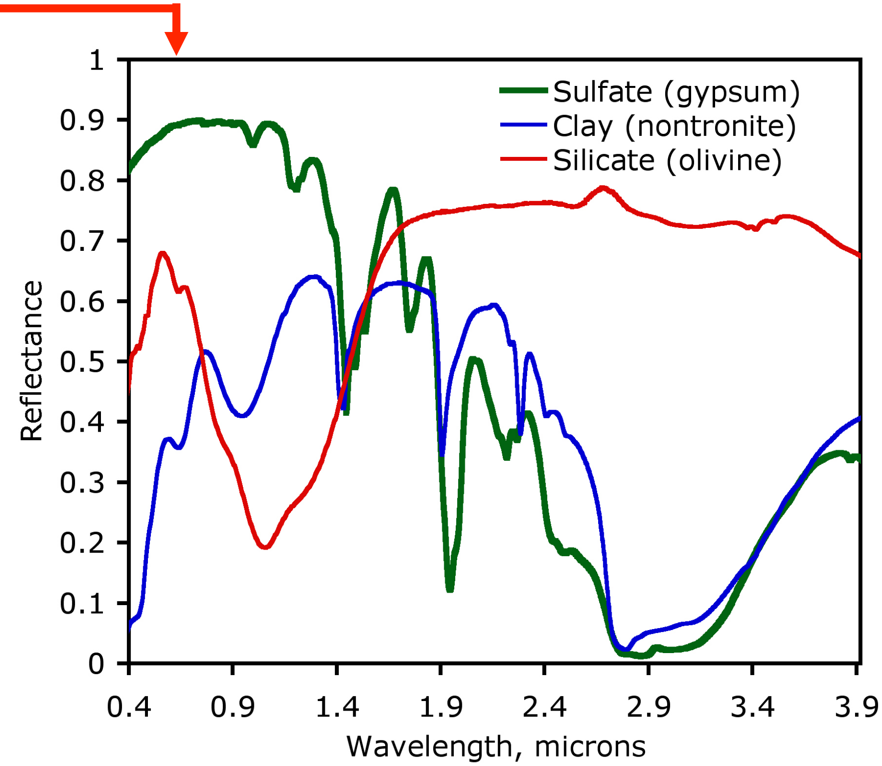
Wavelength range	0.4-3.9 μm
Spectral sampling	6.55 nm/channel
Spatial sampling	18 m/pixel from 300 km

CRISM Optics



Basic Structure of the Data: Successive Frames Acquired Along Track



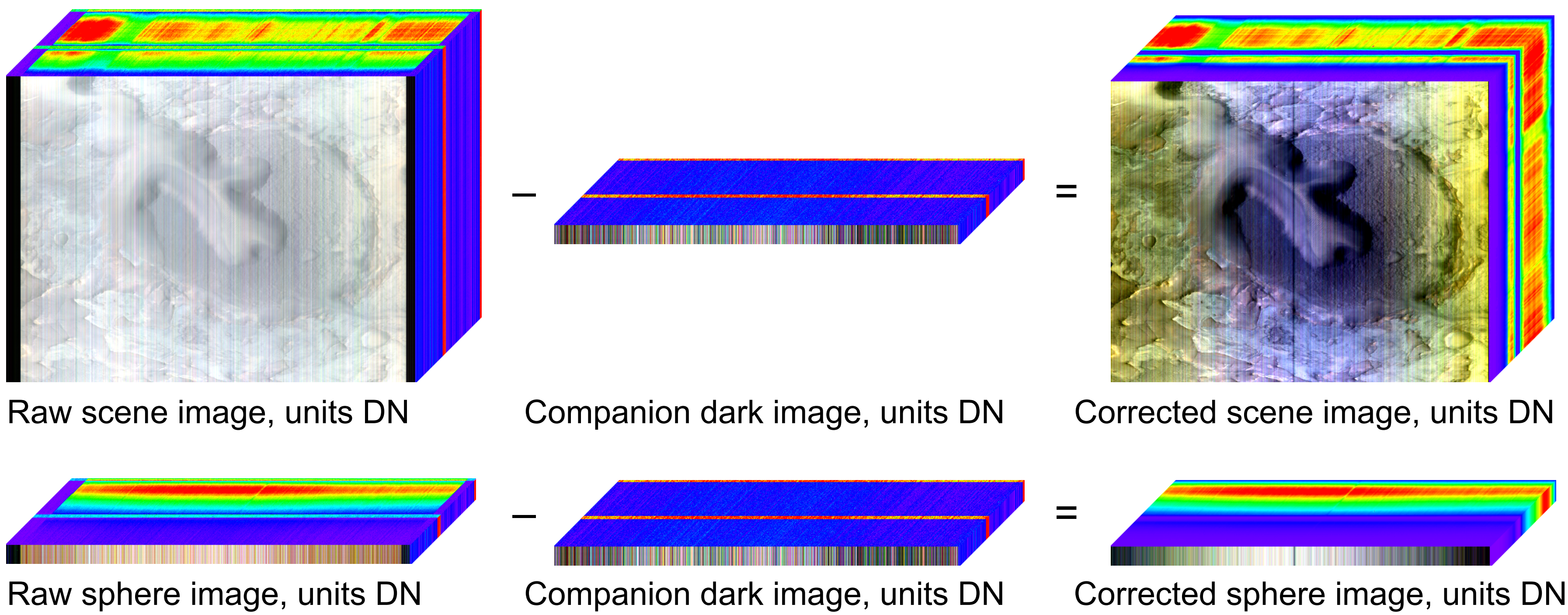


Each readout of the detector is 1 line of a spatial image. The whole image is built as MRO moves along its ground track.

Each pixel has a spectrum whose absorptions can be compared with minerals

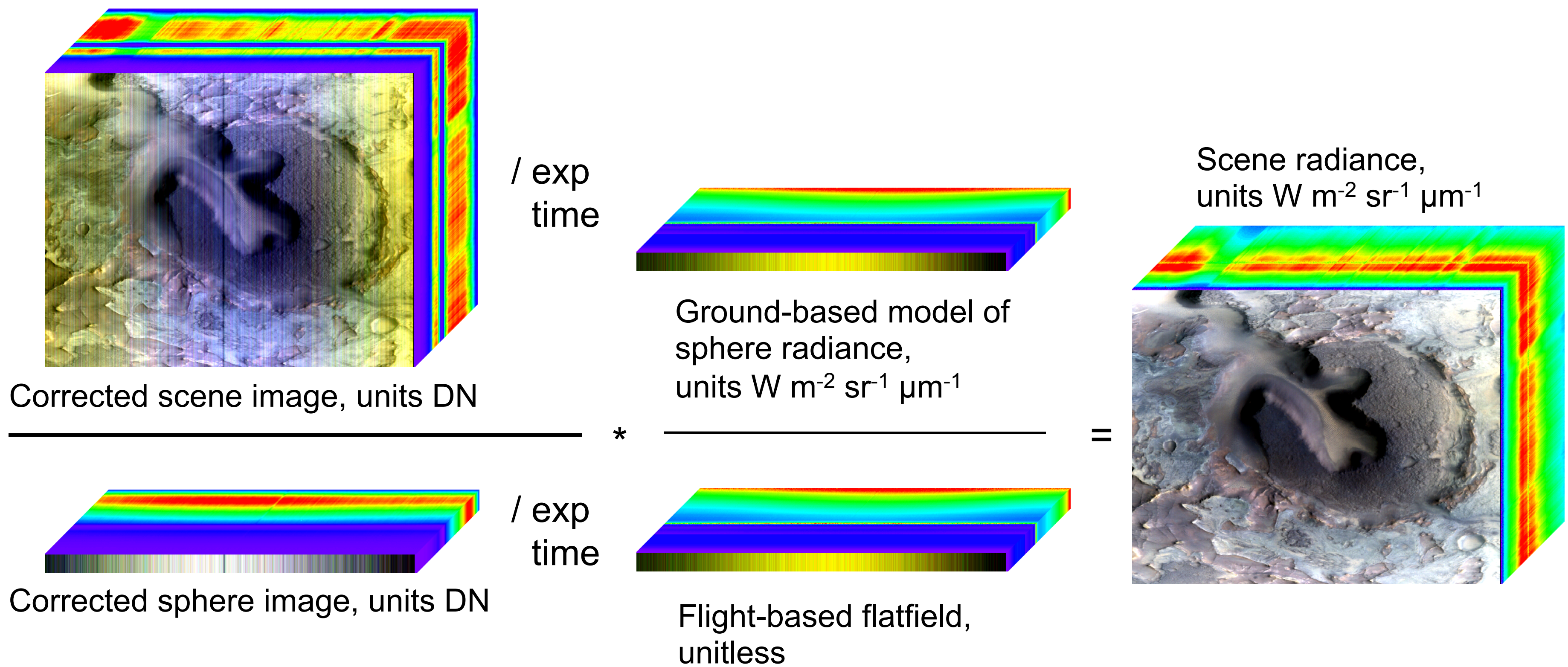
Simplified Calibration Pipeline (1/3)

- All scene images are calibrated to radiance using internal calibrations to remove time-variable instrumental effects
- The first correction is to subtract shutter-closed dark measurements from the scene and from a sphere measurement taken close in time



Simplified Calibration Pipeline (2/3)

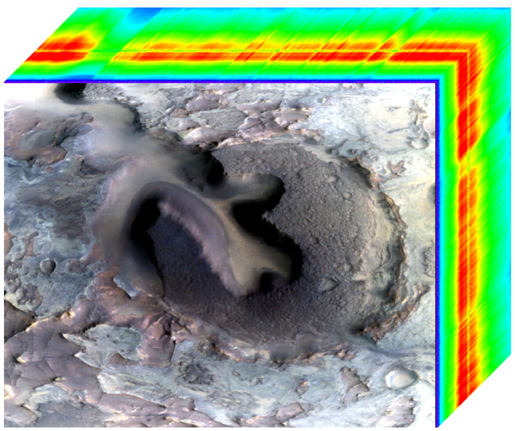
- The corrected scene and sphere images are both divided by exposure time to yield values linearly related to radiance
- The scene is ratioed to the sphere, multiplied by a ground-based model of the sphere's radiance, and divided by a flight-based flatfield
- The result is scene radiance



Simplified Calibration Pipeline (3/3)

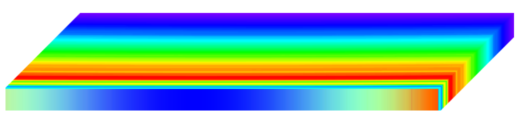
- To convert radiance to I/F, the solar flux at 1 AU is convolved with the bandpasses for each CRISM pixel
- The radiance is divided by the solar flux scaled to Mars' solar distance
- The result is I/F

Scene radiance,
units W m^{-2} sr^{-1} μm^{-1}

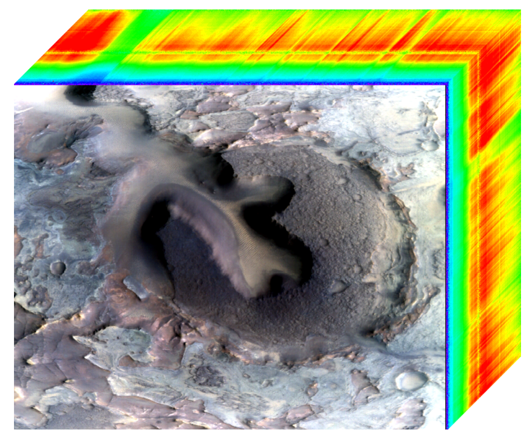


* (solar distance in AU)^2 * π

=



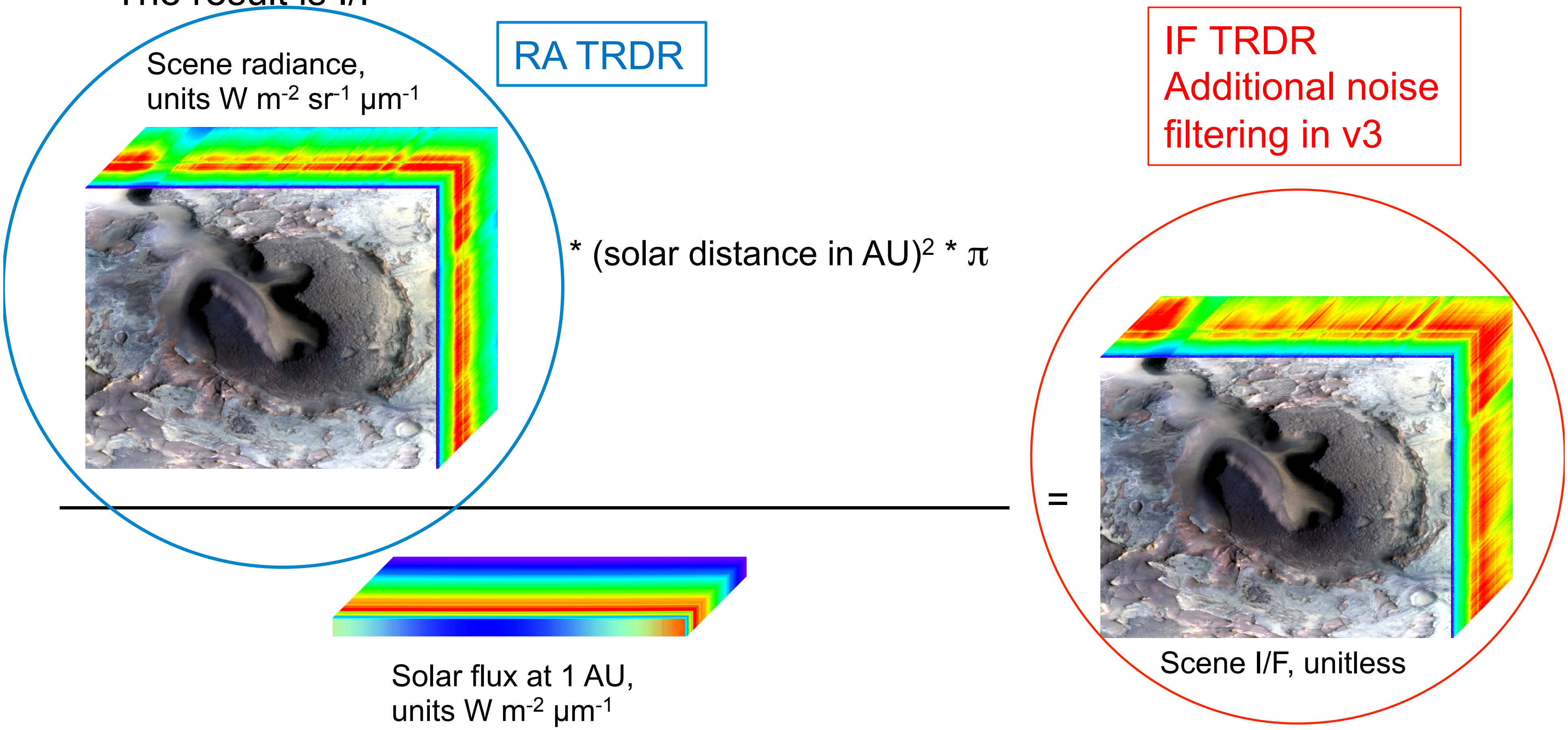
Solar flux at 1 AU,
units W m^{-2} μm^{-1}



Scene I/F, unitless

Simplified Calibration Pipeline (3/3)

- To convert radiance to I/F, the solar flux at 1 AU is convolved with the bandpasses for each CRISM pixel
- The radiance is divided by the solar flux scaled to Mars' solar distance
- The result is I/F



CRISM Observation Types

Key Instrument Settings Control the Type of Observation being Taken

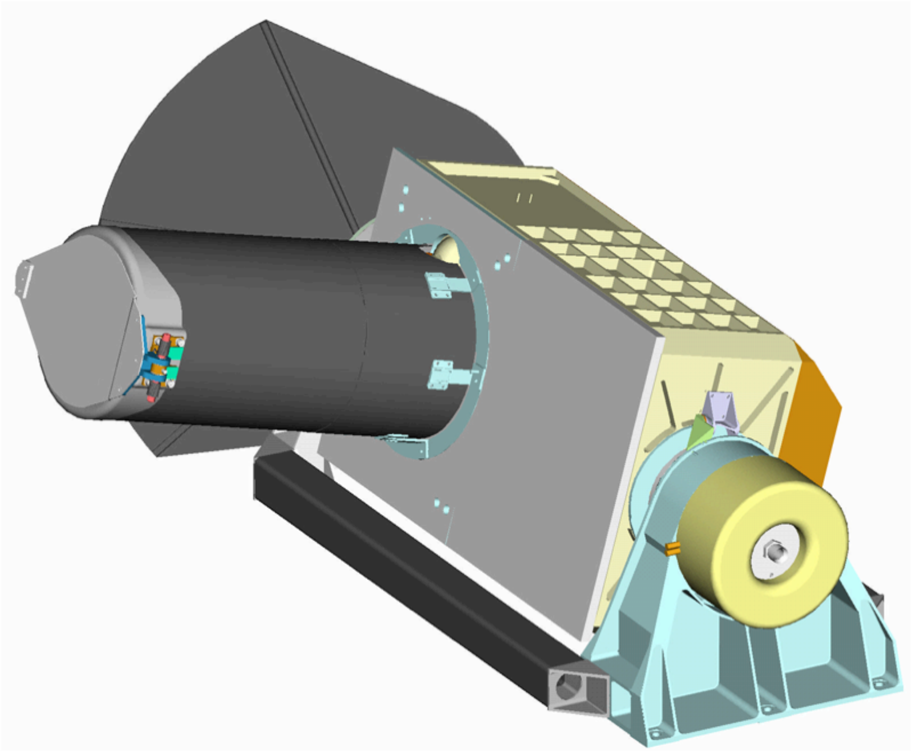
Primary variables that are set to define observation types

- **Pointing**
  - **Fixed, generally at nadir**
  - **Track a point and repeatedly scan across it (nadir or limb)**
- **Number of wavelengths**
  - **All 544 with useful data**
  - **Subsets (72, 94, or 262 selected VNIR+IR wavelengths or all 107 VNIR) for global mapping**

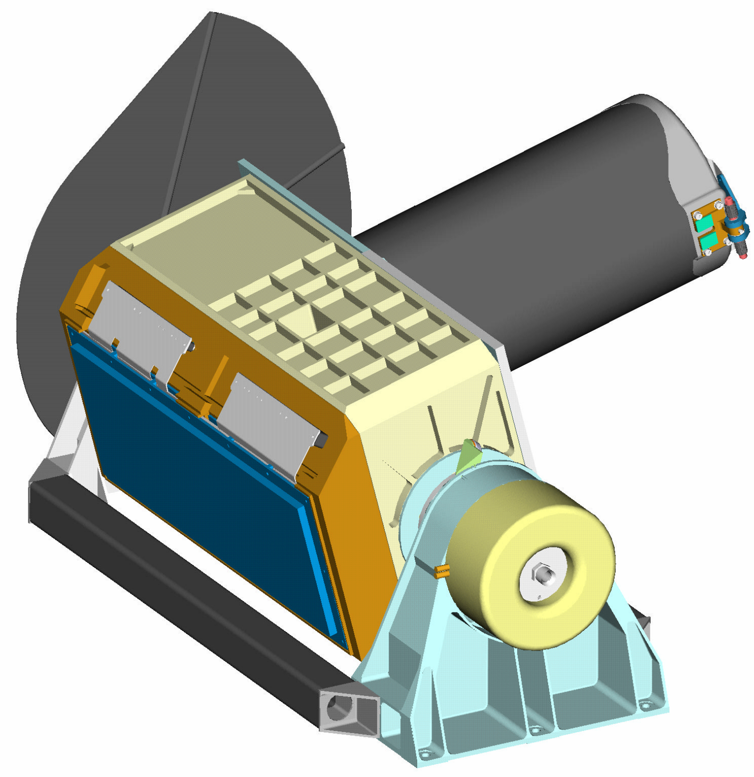
These variables are set to manage data volume and to "square" the pixels

- Frame rate
  - 1 Hz (for internal calibration)
  - 3.75 Hz (hyperspectral observations)
  - 15 or 30 Hz (global mapping)
- Spatial pixel binning
  - None (18 m) or 2x (36 m) for high-resolution observations
  - 5x (100 m) or 10x (200 m) for global mapping

CRISM Rotation



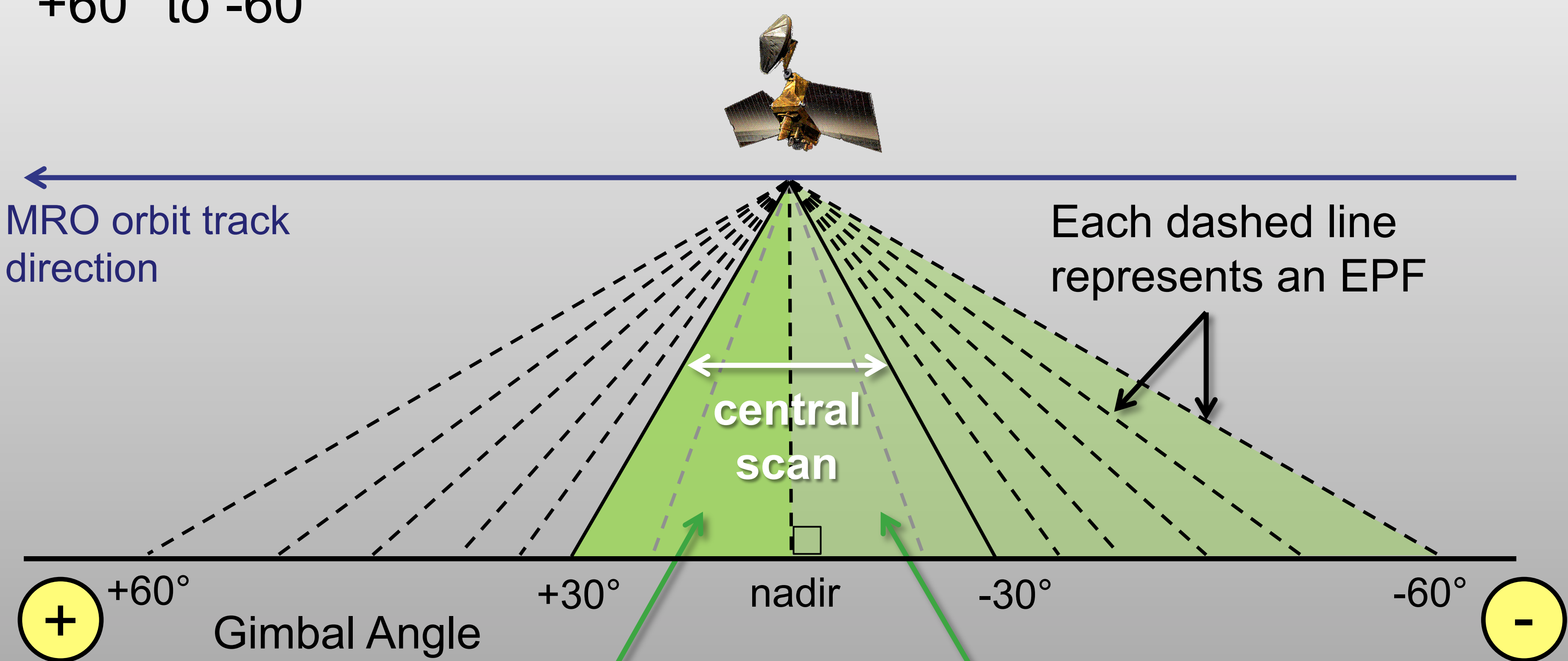
+60º



-60º

Observing Schematic & Gimbal Range of Motion

Original range of gimbal motion
+60° to -60°

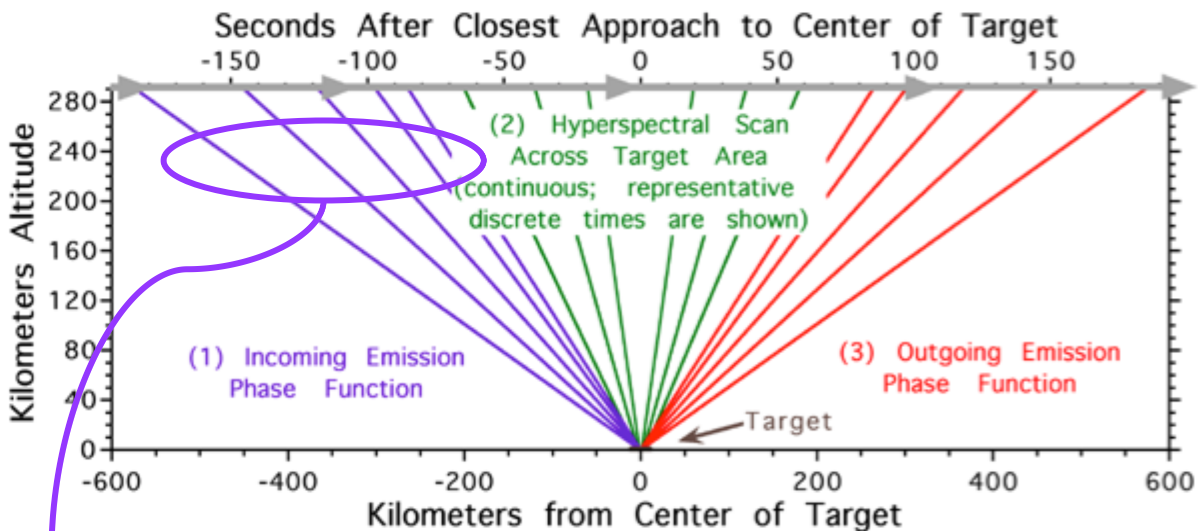


Second restricted range of motion **+30° to nadir**
(from 2012_275 to present)

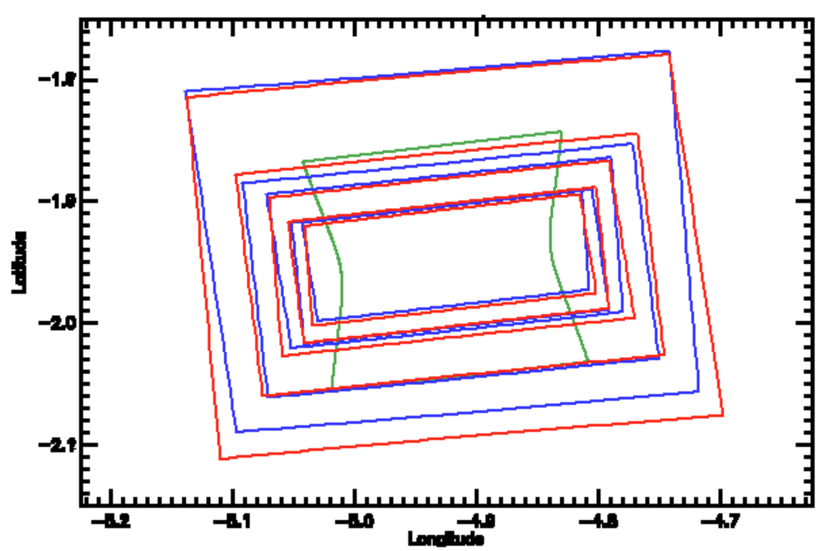
First restricted range of motion **+30° to -60°**
(from 2010_280 to 2012_146)

CRISM

First Basic Observation Type: Gimbaled
(example shown is Full-Resolution Targeted)



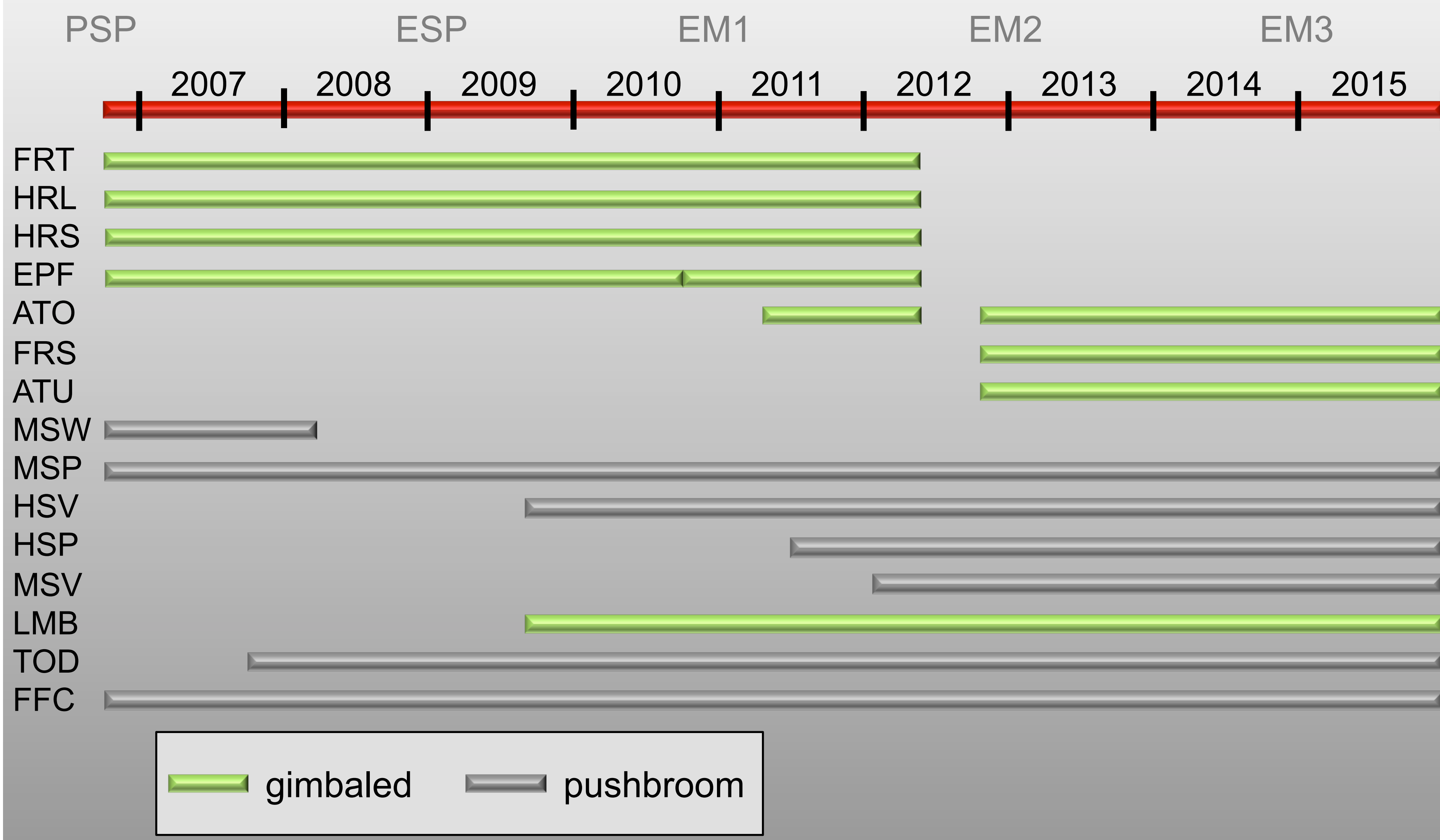
1st 5 images discontinued Sep. 2010 due to gimbal stickiness



Idealized footprints for target at nadir

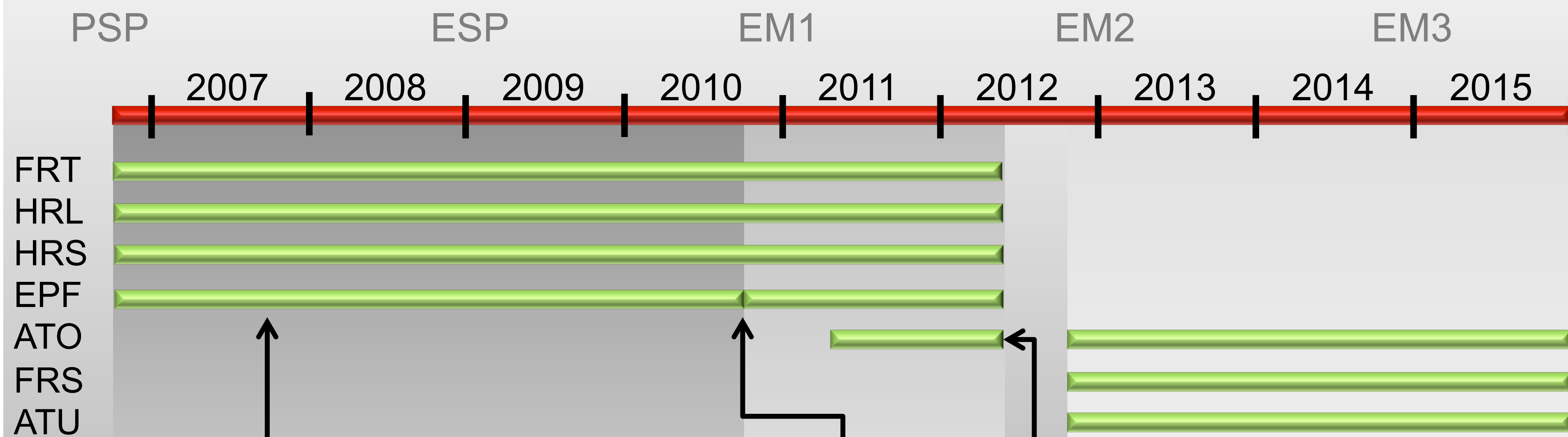
- "Targeted" because s/c actively points
- Up to 11 images at varying emission angles: <u>"Emission phase function"</u>
- Central image may be unbinned (18 m/pixel), 2x binned (36 m/pixel), or 10x binned (~180 m/pixel)
- 1st 5 and last 5 are 10x binned
- Central high-resolution swath for geology; whole set to separate surface/ atmosphere

Timeline of Observing Modes



Timeline of Observing Modes: Gimbaled

CRISM



First Generation ("Classic")

Gimbal range +/-60°
- 5 incoming EPFs
- Central scan
- 5 outgoing EPFs

Restricted gimbal range (-60° to +30°)
- 5 outgoing EPFs
- Central scan

- 2 segments added to EPF mode

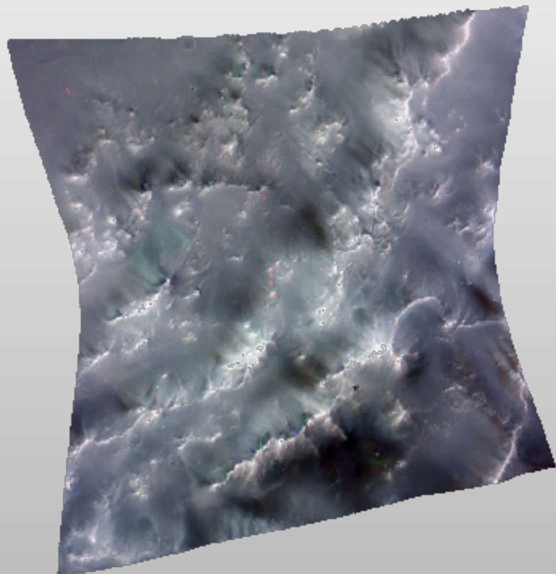
- ATOs acquired but labeled FRTs

Second Generation

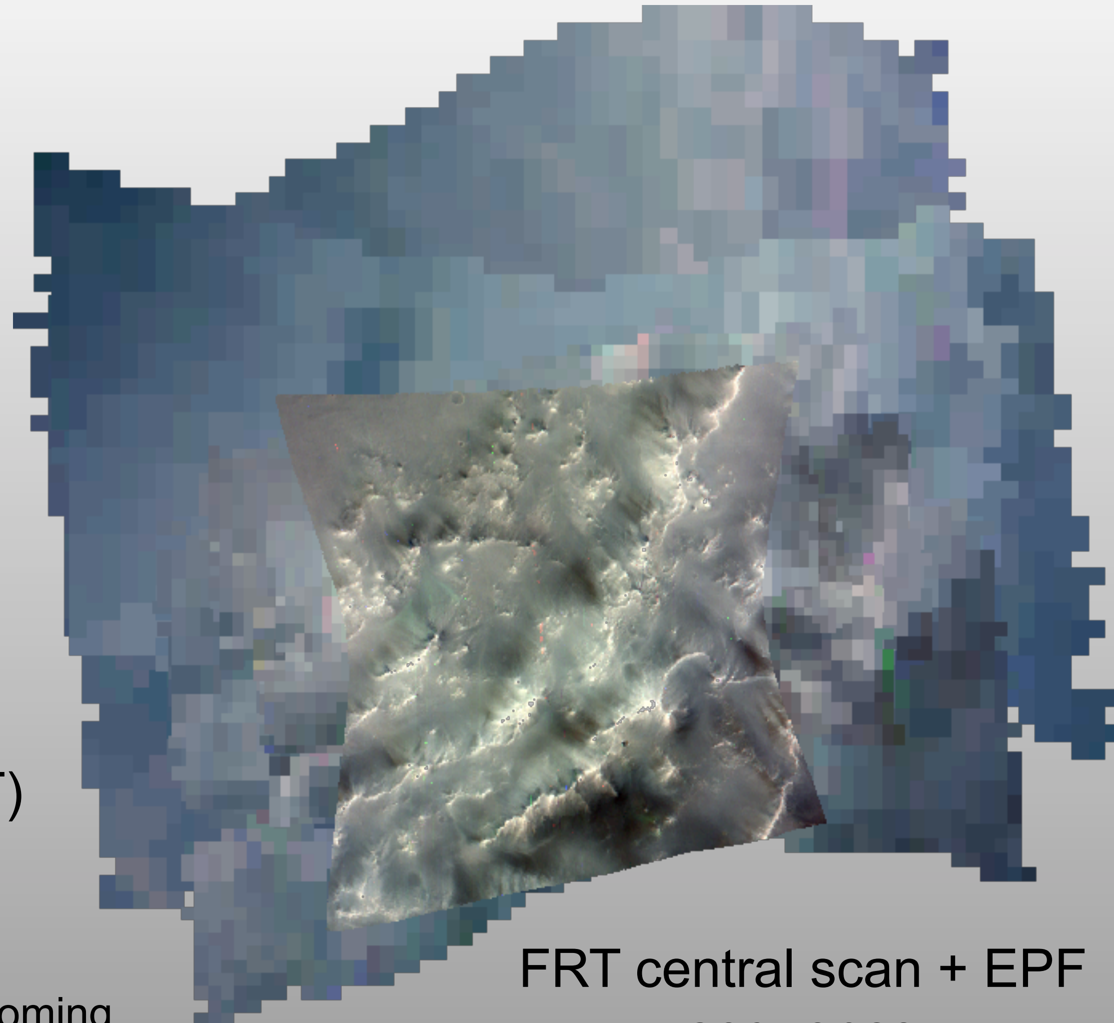
Restricted gimbal range (-30° to nadir)
- no EPFs
- half central scan

Classic Targeted Observing Modes: FRT, EPF

~20 m/pix



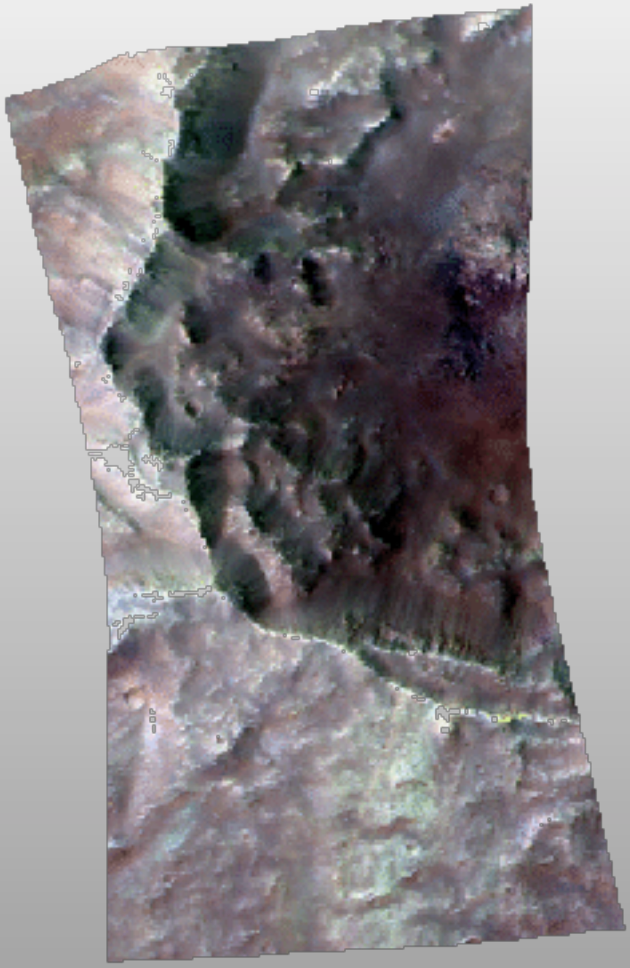
Full **R**esolution **T**argeted (FRT) central scan only



FRT central scan + EPF sequence

- **EPF mode** consists of 5 (or 6) incoming and outgoing scans plus a 10x-binned, ~200 m/pix central scan
- Each FRT/HRL/HRS also has 5 or 6 EPF segments but the central scan is ~20 or ~40 m/pix.

Classic Targeted Observing Modes: HRL, HRS



Half Resolution Long (HRL)

40 m/pix

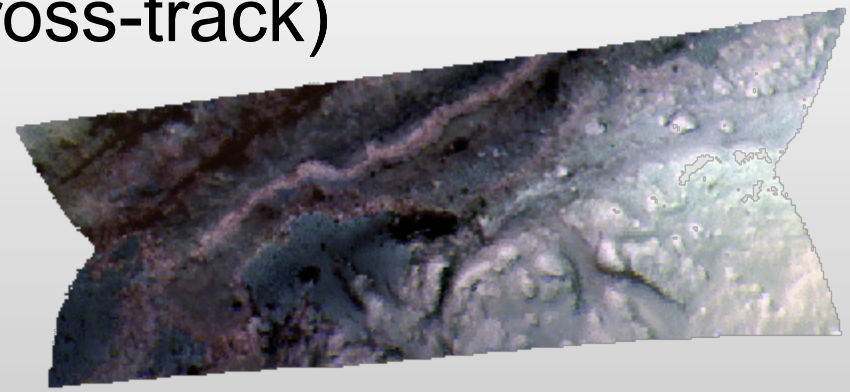
Half Resolution Short (HRS)

Second Generation Targeted Observing Modes

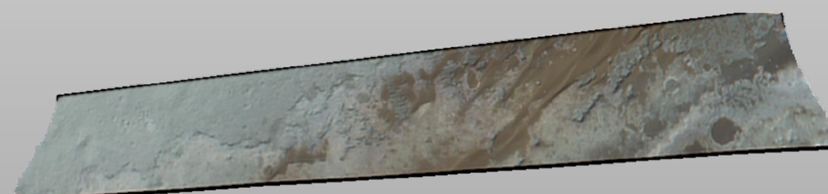
~20 m/pix (cross-track)

Full **R**esolution **S**hort (FRS)
(~20 m/pix)

Along **T**rack **U**ndersampled (ATU)
(~40 m/pix downtrack)

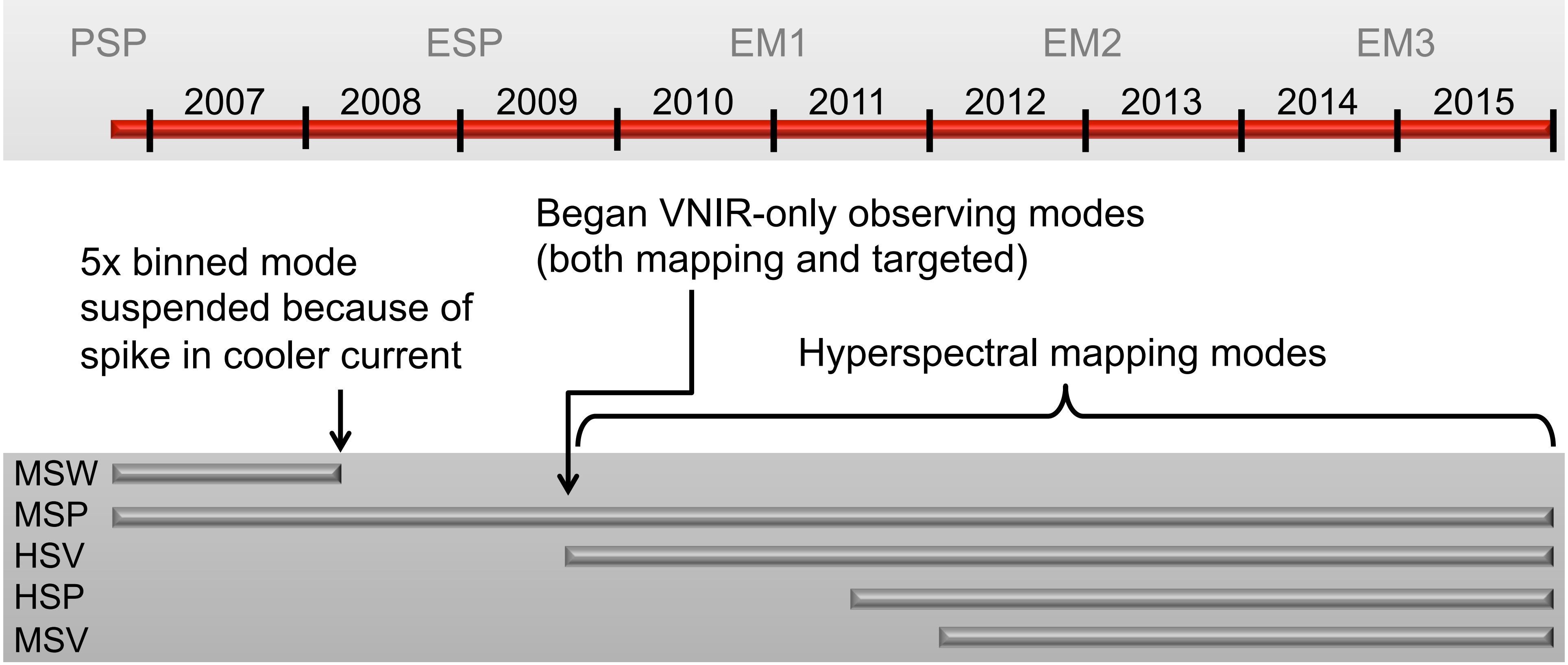


Along **T**rack **O**versampled (ATO)
(variant of FRT before 2012_142)
(highest spatial resolution in center)



ATO (after 2012_142)
(up to ~8 m/pix downtrack, but requires special processing for increased resolution)

CRISM Timeline of Observing Modes: Mapping



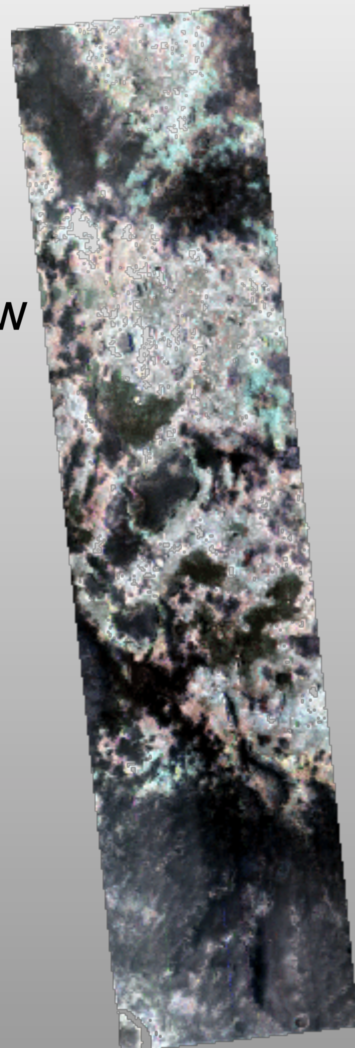
MSW, MSV = 5x binned = 100 m/pix
MSP, HSV, HSP = 10x binned = 200 m/pix

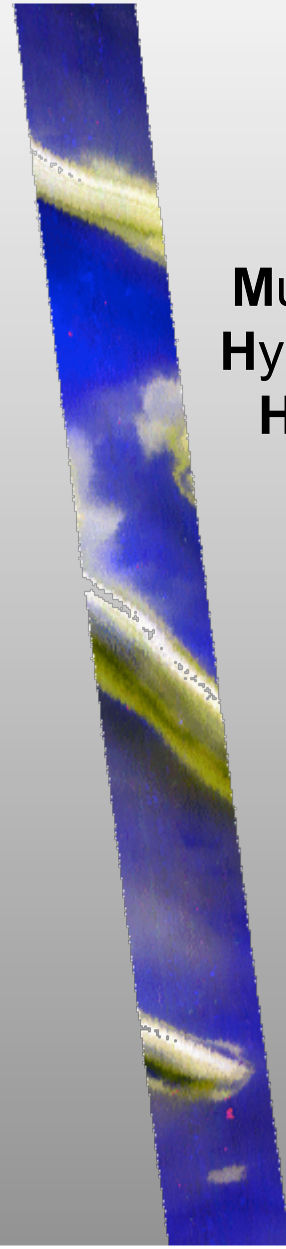
Mapping Modes

100 m/pix

Multi**S**pectral **W**indow (MSW)

Multi**S**pectral **V**NIR (MSV)



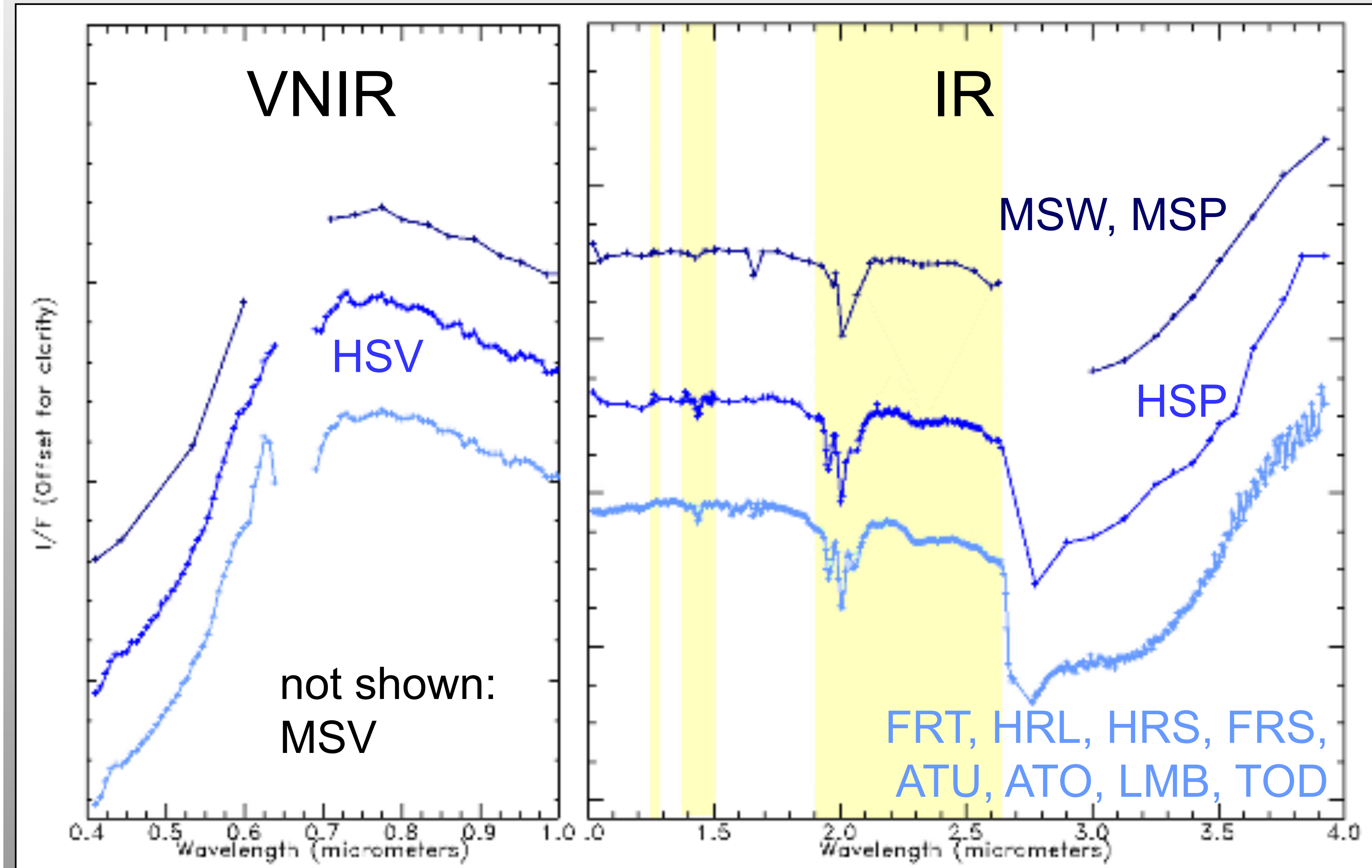


200 m/pix

Multi**SP**ectral Mapping (MSP)
Hyper**SP**ectral Mapping (HSP)
Hyper**S**PectraI **V**NIR (HSV)

All mapping mode observations can vary in length: ~45, 180, or 540 km

Mapping Modes: Spectral Sampling



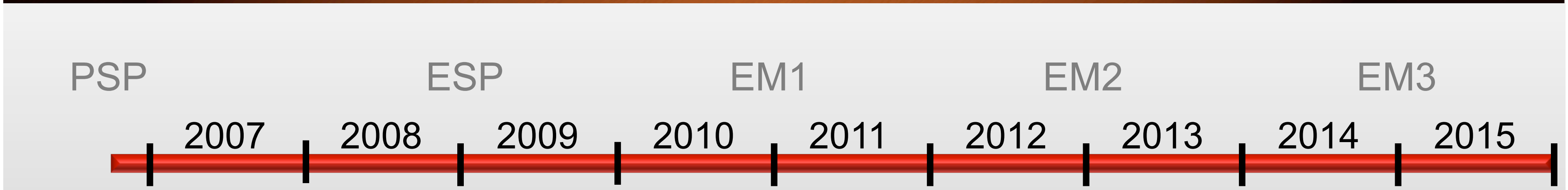
number of bands:

VNIR	IR
19	55
107	154
107	436

VNIR-only modes:

	VNIR	IR
HSV	107	0
MSV	90	0

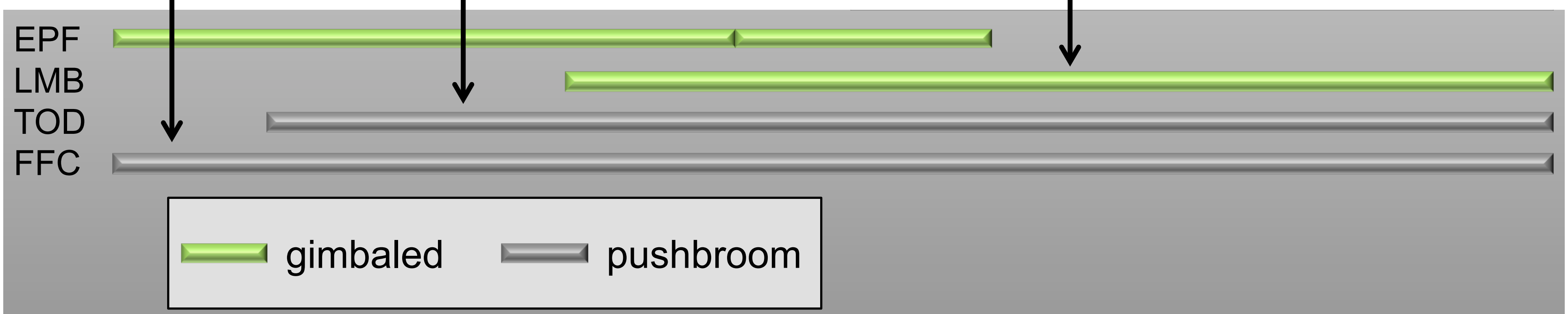
Timeline of Observing Modes: Atmospheric and Calibrations



Tracking **O**ptical **D**epth (TODs): Hyperspectral, 10x binned snapshots to help fill spatial and temporal gaps between targeted observations

Flat **F**ield **C**alibrations (FFCs): Acquired throughout mission

LiMB Scans (LMBs): Requires spacecraft pitch maneuver to view limb of planet, low-angle gimbal scan



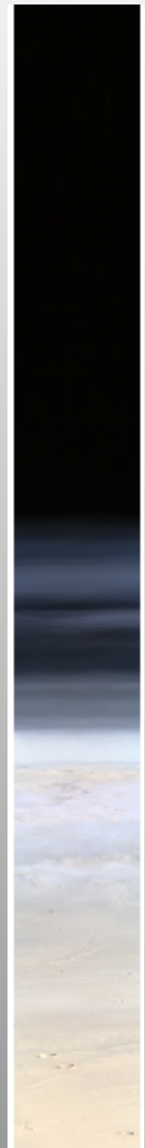
Atmospheric Observations

LMB

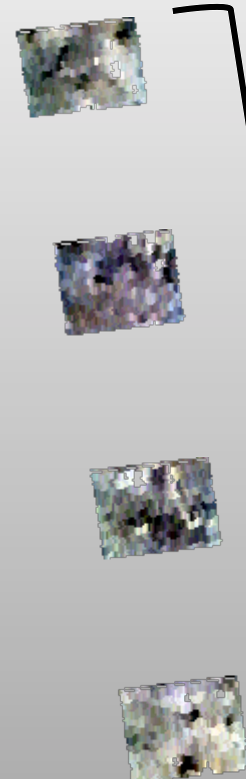
space

atmosphere

surface

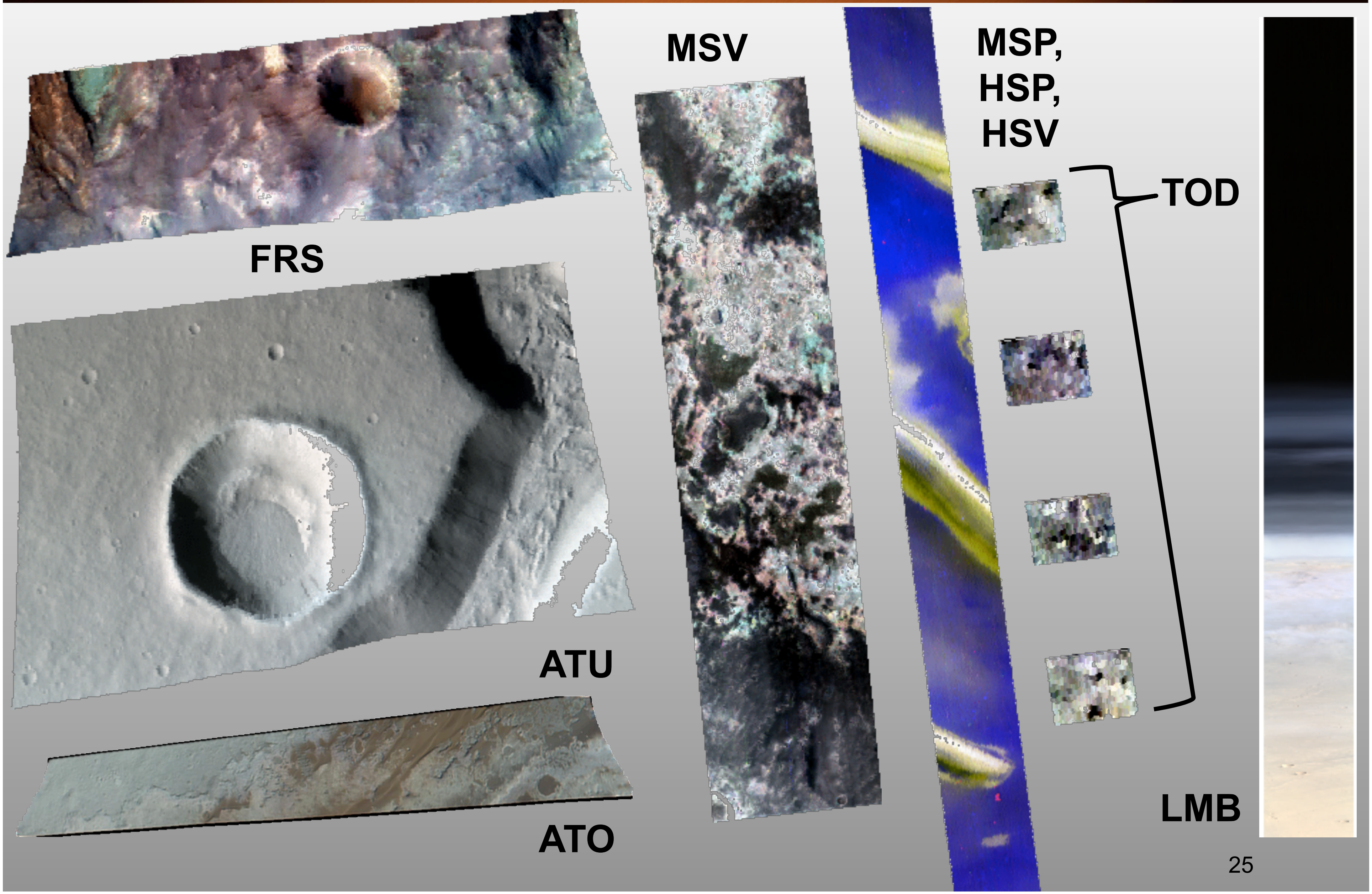


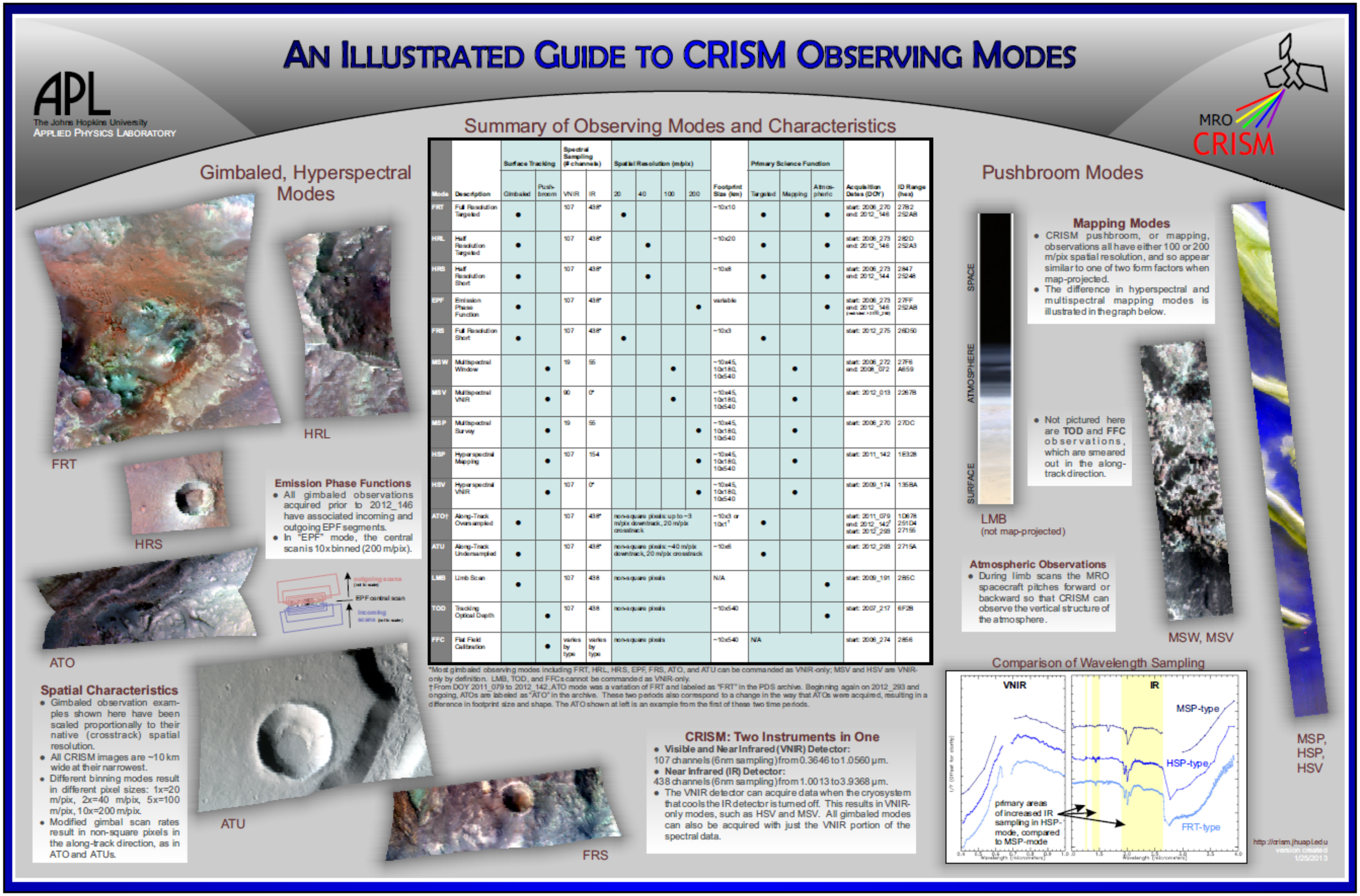
TOD



- 4 hyperspectral snapshots of surface
- Pixels are elongated downtract – similar to flat fields

Summary: Current Suite of Observing Modes





An Illustrated Guide to CRISM Observing Modes

APL
The Johns Hopkins University
Applied Physics Laboratory

MRO CRISM

Gimbaled, Hyperspectral Modes

FRT

HRL

HRS

ATO

ATU

FRS

Emission Phase Functions

- All gimbaled observations acquired prior to 2012_146 have associated incoming and outgoing EPF segments.
- In "EPF" mode, the central scan is 10x binned (200 m/pix).

outgoing scans (not to scale)
EPF central scan
incoming scans (not to scale)

Spatial Characteristics

- Gimbaled observation examples shown here have been scaled proportionally to their native (crosstrack) spatial resolution.
- All CRISM images are ~10 km wide at their narrowest.
- Different binning modes result in different pixel sizes: 1x=20 m/pix, 2x=40 m/pix, 5x=100 m/pix, 10x=200 m/pix.
- Modified gimbal scan rates result in non-square pixels in the along-track direction, as in ATO and ATUs.

Summary of Observing Modes and Characteristics

Mode	Description	Surface Tracking: Gimbaled	Surface Tracking: Push-broom	Spectral Sampling (# channels): VNIR	Spectral Sampling (# channels): IR	Spatial Resolution (m/pix): 20	40	100	200	Footprint Size (km)	Primary Science Function: Targeted	Mapping	Atmospheric	Acquisition Dates (DOY)	ID Range (hex)
FRT	Full Resolution Targeted	•		107	438*	•				~10x10	•		•	start: 2006_270 end: 2012_146	27B2 252AB
HRL	Half Resolution Targeted	•		107	438*		•			~10x20	•		•	start: 2006_273 end: 2012_146	282D 252A3
HRS	Half Resolution Short	•		107	438*		•			~10x8	•		•	start: 2006_273 end: 2012_144	2847 25248
EPF	Emission Phase Function	•		107	438*				•	variable			•	start: 2006_273 end: 2012_146	27FF 252AB
FRS	Full Resolution Short	•		107	438*	•				~10x3	•			start: 2012_275	26D50
MSW	Multispectral Window		•	19	55			•		~10x45, 10x180, 10x540		•		start: 2006_272 end: 2008_072	27F6 A659
MSV	Multispectral VNIR		•	90	0*			•		~10x45, 10x180, 10x540		•		start: 2012_013	2267B
MSP	Multispectral Survey		•	19	55				•	~10x45, 10x180, 10x540		•		start: 2006_270	27DC
HSP	Hyperspectral Mapping		•	107	154				•	~10x45, 10x180, 10x540		•		start: 2011_142	1E328
HSV	Hyperspectral VNIR		•	107	0*				•	~10x45, 10x180, 10x540		•		start: 2009_174	135BA
ATO†	Along-Track Oversampled	•		107	438*	non-square pixels: up to ~3 m/pix downtrack, 20 m/pix crosstrack				~10x3 or 10x1†	•			start: 2011_079 end: 2012_142† start: 2012_293	1D678 251D4 27155
ATU	Along-Track Undersampled	•		107	438*	non-square pixels: ~40 m/pix downtrack, 20 m/pix crosstrack				~10x6	•			start: 2012_293	2715A
LMB	Limb Scan	•		107	438	non-square pixels				N/A			•	start: 2009_191	285C
TOD	Tracking Optical Depth		•	107	438	non-square pixels				~10x540			•	start: 2007_217	6F2B
FFC	Flat Field Calibration		•	varies by type	varies by type	non-square pixels				~10x540	N/A			start: 2006_274	2856

*Most gimbaled observing modes including FRT, HRL, HRS, EPF, FRS, ATO, and ATU can be commanded as VNIR-only; MSV and HSV are VNIR-only by definition. LMB, TOD, and FFCs cannot be commanded as VNIR-only.
†From DOY 2011_079 to 2012_142, ATO mode was a variation of FRT and labeled as "FRT" in the PDS archive. Beginning again on 2012_293 and ongoing, ATOs are labeled as "ATO" in the archive. These two periods also correspond to a change in the way that ATOs were acquired, resulting in a difference in footprint size and shape. The ATO shown at left is an example from the first of these two time periods.

CRISM: Two Instruments in One

- **Visible and Near Infrared (VNIR) Detector:**
107 channels (6nm sampling) from 0.3646 to 1.0560 μm.
- **Near Infrared (IR) Detector:**
438 channels (6nm sampling) from 1.0013 to 3.9368 μm.
- The VNIR detector can acquire data when the cryosystem that cools the IR detector is turned off. This results in VNIR-only modes, such as HSV and MSV. All gimbaled modes can also be acquired with just the VNIR portion of the spectral data.

Pushbroom Modes

Mapping Modes

- CRISM pushbroom, or mapping, observations all have either 100 or 200 m/pix spatial resolution, and so appear similar to one of two form factors when map-projected.
- The difference in hyperspectral and multispectral mapping modes is illustrated in the graph below.

SPACE
ATMOSPHERE
SURFACE

LMB
(not map-projected)

- Not pictured here are **TOD** and **FFC** observations, which are smeared out in the along-track direction.

Atmospheric Observations

- During limb scans the MRO spacecraft pitches forward or backward so that CRISM can observe the vertical structure of the atmosphere.

MSW, MSV

MSP, HSP, HSV

Comparison of Wavelength Sampling

http://crism.jhuapl.edu
version created 1/25/2013

http://crism.jhuapl.edu/instrument/images/observing_modes_poster_v5.pdf

Summary

- Current Observing Modes:
  - VNIR, VNIR+IR Targeted: FRS, ATO ATU
  - VNIR Mapping: MSV, HSV
  - VNIR+IR Mapping/Atmospheric: MSP, HSP, TOD, LMB
- New Targets
  - New targets always welcome! Don’t wait to submit targets, despite 1-of-4 cold cycle frequency.

APL

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APPLIED PHYSICS LABORATORY